Claims

1. An off-axis projection system for displaying an optical image on a display surface based on input image data, comprising:

(a) an image processing unit for receiving the input image data and generating distortion-compensated image data;

(b) a projection light engine coupled to the image processing unit for receiving the distortion-compensated image data and projecting a distortion-compensated optical image that corresponds to the distortion-compensated image data; and,

(c) an optical reflection assembly coupled to the projection light engine, said optical reflection assembly comprising at least one curved mirror, said curved mirror being positioned in the optical path of the distortion-compensated optical image emerging from a projection lens for producing a displayed optical image with reduced distortion on the display surface;

wherein, said image processing unit is adapted to distortion-compensate the optical image represented by the input image data such that when said distortion-compensated optical image is projected through the projection light engine and reflected off the optical reflection assembly, the optical and geometric distortions associated with said projection light engine and the optical reflection assembly are substantially eliminated in the displayed optical image.

2. The projection system of claim 1, wherein the curved mirror is an aspherical rotationally non-symmetric mirror having a vertically oriented concave surface and a horizontally oriented surface with a varying degree of concave or convex curvature on an upper surface that smoothly transitions to a varying degree of convex curvature on a lower surface for reducing spatial distortion on the displayed optical image.

3. The projection system of claim 2, wherein the curved mirror has a small degree of horizontal convex curvature on an upper portion and a larger

degree of horizontal convex curvature on a lower portion for reducing spatial distortion on the displayed optical image.

4. The projection system of claim 1, further comprising a corrector lens positioned in the optical path of the distortion-compensated optical image between the projection light engine and the curved mirror, said corrector lens being shaped to compensate for the defocusing caused by said curved mirror.

5. The projection system of claim 1, wherein the projection light engine comprises an aspherical rotationally non-symmetric lens being shaped to compensate for defocusing caused by said curved mirror.

6. The projection system of claim 1, wherein the image processing unit is adapted to scale the input image data to the aspect ratio and resolution of the projection light engine.

7. The projection system of claim 1, wherein said projection light engine comprises:

(i) a light generator for generating a beam of light;

(ii) a display device positioned in front of the light generator for displaying the distortion-compensated optical image; and

(iii) projection optics positioned in front of the display device for projecting and focusing the distortion-compensated optical image.

8. The projection system of claim 7, wherein the projection optics includes a projection lens and wherein an optical axis of the projection lens is offset from an optical axis of thè display device for adjusting the position of the beam of light from the light generator with respect to the on-axis direction of the path of the distortion-compensated optical image in order to further compensate for keystone distortion and spot size in the displayed optical image.

9. The projection system of claim 7, wherein the projection optics includes a projection lens and wherein an optical axis of the projection lens is tilted

from an optical axis of the display device for adjusting the position of the beam of light from the light generator with respect to the on-axis direction of the path of the distortion compensated optical image in order to further reduce spot size and improve MTF in the displayed optical image.

10. The projection system of claim 7, wherein the projection optics include a projection lens and wherein an optical axis of the projection lens is offset and tilted from an optical axis of the display device for adjusting the position of the beam of light from the light generator with respect to the on-axis direction of the path of the distortion-compensated optical image in order to further compensate for keystone distortion and spot size in the displayed optical image.

11. The projection system of claim 7, wherein said light generator is an illumination subsystem, said display device is a micro-display based light modulating subsystem, and said optical assembly is an assembly of lens elements.

12. The projection system of claim 11, wherein the micro-display device is shaped to compensate for keystone and other spatial distortions.

13. The projection system of claim 1, wherein said optical reflection assembly additionally comprises a first flat mirror having a planar reflective surface that is placed within the optical path of the distortion-compensated optical image.

14. The projection system of claim 13, further comprising a second flat mirror, such that the optical path of the distortion-compensated optical image impinges onto the surface of the second flat mirror, reflects to the curved mirror and is then reflected from the surface of the curved mirror onto the surface of the primary flat mirror which finally directs the light rays to the display surface.

15. The projection system of claim 13, further comprising a second curved mirror, such that the optical path of the distortion-compensated optical image passes onto the surface of the second curved mirror, reflects from the surface of the curved mirror and then from the surface of the primary flat mirror.

16. The projection system of claim 1, wherein said image processing unit, projection light engine, and optical reflection assembly are adapted to operate in a rear projection configuration.

17. The projection system of claim 1, wherein the curved mirror is replaced by a Fresnel mirror.

18. The projection system of claim 1, wherein the image processing unit comprises:

i) a luminance correction stage for adjusting pixel brightness in the input image data to produce luminance adjusted input image data; and,

ii) an image warping stage connected to the luminance correction stage for receiving the luminance adjusted input image data and generating the distortion-compensated image data.

19. The projection system of claim 18, wherein the luminance correction stage individually processes different spectral passbands associated with the input image data.

20. The projection system of claim 18, wherein the image warping stage individually processes different spectral passbands associated with the luminance adjusted input image data.

21. An off-axis projection method for displaying an optical image on a display surface of an off-axis projection system based on input image data, comprising the steps of:

(a) receiving input image data and electronically generating distortion-compensated image data;

(b) providing a distortion-compensated optical image that corresponds to the distortion-compensated image data; and,

(c) reflecting the distortion-compensated optical image in an optical reflection assembly to produce a displayed optical image for projection on the display surface, said assembly comprising at least one curved mirror, said curved mirror being positioned in the optical path of the distortion-compensated optical image emerging from the projection lens for producing a displayed optical image with reduced distortion on the display surface;

wherein step (a) comprises distortion-compensating the optical image represented by the image data such that when said distortion-compensated optical image is reflected off the optical reflection assembly, the optical and geometric distortions associated with the projection system are substantially eliminated in the displayed optical image.

22. The projection method of claim 21, wherein step (c) includes providing the curved mirror as an aspherical rotationally non-symmetric mirror having a vertically oriented concave surface and a horizontally oriented surface with a varying degree of convex or concave curvature on an upper portion that smoothly transitions to a varying degree of convex curvature on a lower portion for reducing spatial distortion on the displayed optical image.

23. The projection method of claim 22, wherein the curved mirror has a small degree of horizontal convex curvature on an upper portion and a larger degree of horizontal convex curvature on a lower portion for reducing spatial distortion on the displayed optical image.

24. The projection method of claim 21, wherein step (c) further comprises directing the distortion-compensated optical image through a corrector lens positioned in the optical path of the distortion-compensated optical image before the optical reflection assembly, said corrector lens being shaped to compensate for the defocusing caused by the curved mirror used in step (c).

25. The projection method of claim 21, wherein step (c) further comprises directing the distortion-compensated optical image through an aspherical rotationally non-symmetric lens being shaped to compensate for the defocusing caused by the curved mirror.

26. The projection method of claim 21, wherein steps (b) and (c) further comprise generating a beam of light, positioning a display device to produce the distortion-compensated optical image, and projecting and focusing the distortion-compensated optical image.

27. The projection method of claim 26, wherein steps (b) and (c) further comprise shifting an optical axis of said display device with respect to an optical axis of a projection lens in order to further compensate for keystone distortion in the displayed optical image.

28. The projection method of claim 26, wherein steps (b) and (c) further comprise tilting an optical axis of said display device with respect to an optical axis of a projection lens in order to reduce de-focusing and improve MTF in the displayed optical image.

29. The projection method of claim 26, wherein steps (b) and (c) further comprise shifting and tilting an optical axis of said display device with respect to an optical axis of a projection lens in order to further compensate for keystone distortion, reduce de-focusing, and improve MTF in the displayed optical image.

30. The projection method of claim 26, wherein steps (b) and (c) further comprise positioning a light generator before the display device and an optical reflection assembly after the display device, wherein said light generator is an illumination subsystem, said display device is a micro-display-based imaging subsystem, and said optical assembly is an assembly of lens elements.

31. The projection method of claim 21, wherein the method further comprises adding a first flat mirror to said optical reflection assembly wherein the first flat mirror has a planar reflective surface and is placed within the optical path of the distortion-compensated optical image.

32. The projection method of claim 31, wherein step (c) further comprises adding a second flat mirror to said optical reflection assembly, such that the optical path of the distortion-compensated optical image impinges onto the surface of the second flat mirror, reflects onto the surface of the curved mirror and then onto the surface of the primary flat mirror.

33. The projection method of claim 31, wherein step (c) further comprises adding a second curved mirror to said optical reflection assembly, such that the optical path of the distortion compensated optical image impinges onto the surface of the second curved mirror, reflects onto the surface of the first curved mirror and then onto the surface of the primary flat mirror.

34. The projection method of claim 21, wherein the method further comprises operating the projection system in a rear projection configuration.

35. The projection method of claim 21, wherein the method further comprises using a Fresnel mirror in place of the curved mirror.

36. The projection method of claim 21, wherein step (a) comprises:

i) adjusting pixel brightness in the input image data to produce luminance adjusted input image data; and,

ii) warping the luminance adjusted input image data to generate the distortion compensated image data.

37. The projection method of claim 36, wherein step (i) includes individually processing different spectral passbands associated with the input image data.

38. The projection method of claim 36, wherein step (ii) includes individually processing different spectral passbands associated with the luminance adjusted input image data.